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# Stratigraphy of the Webster-Worcester Region, Massachusetts

Barosh, Patrick J.

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# STRATIGRAPHY OF THE WEBSTER-WORCESTER REGION, MASSACHUSETTS

by

Patrick J. Barosh
U.S. Geological Survey
Boston, Massachusetts

Introduction: Many of the major structural-stratigraphic blocks of eastern Massachusetts are juxtaposed between Worcester and northeastern Connecticut (fig. 1), where stratigraphic units characteristic of these blocks can be seen in a relatively small area. The stratigraphy (fig. 2) from oldest to youngest consists of the Plainfield Formation in the north end of the Rhode Island massif; the Marlboro and Nashoba Formations and the Tadmuck Brook Schist of the Clinton-Newbury-Bloody Bluff thrust block; quartzite, metasiltstone-phyllite, and the Eliot Formation in a fault sliver representing the southernmost extension of Merrimack Group rocks from the Clinton area; the Oakdale Formation of the Worcester lowland and the "Paxton Group" and Bigelow Brook Formation in thrust blocks to the west (fig. 1).

## Stratigraphy:

### Plainfield Formation (Precambrian?)

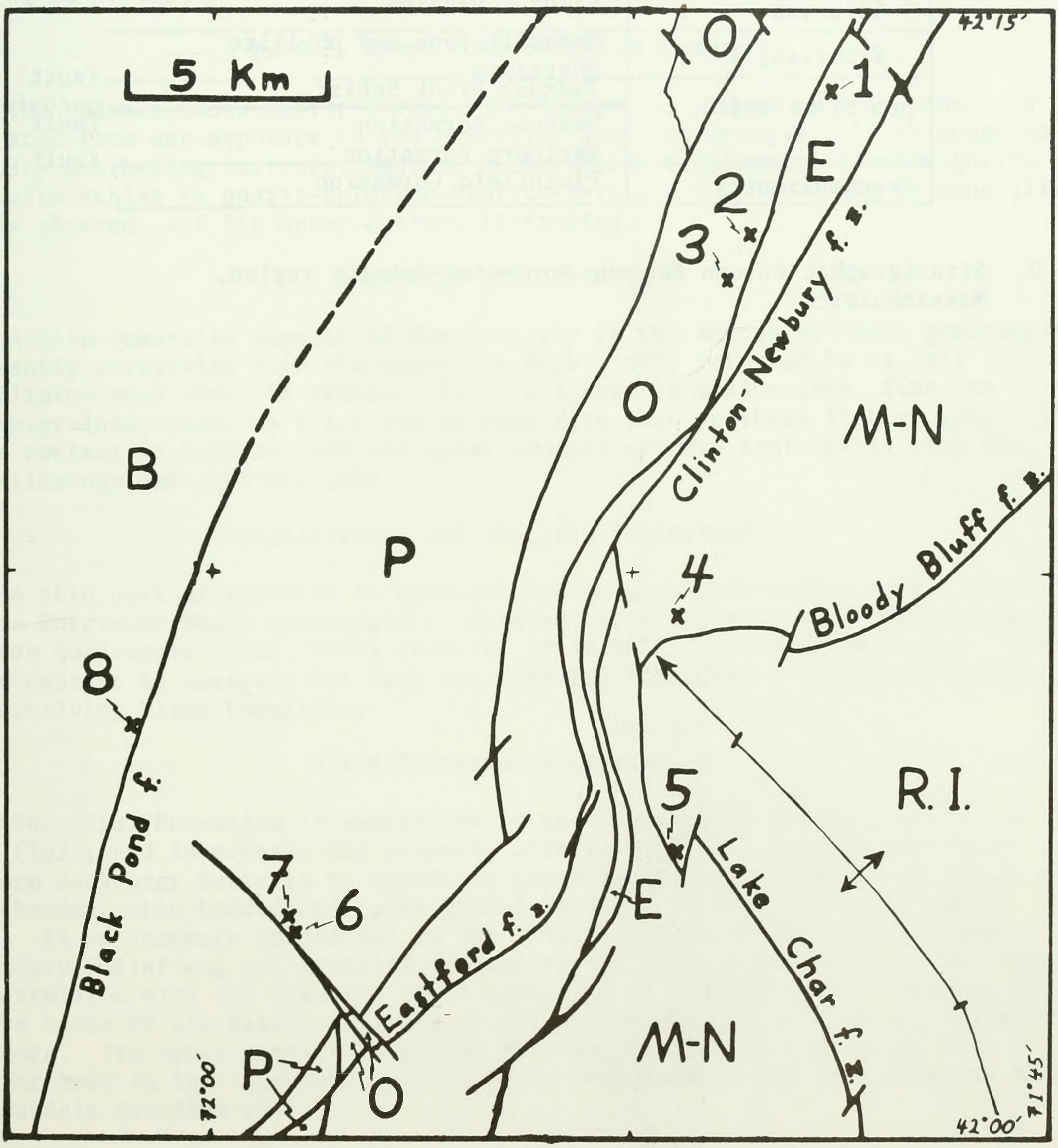
Lundgren (1962) named the Plainfield Formation from exposures in eastern Connecticut. It consists of medium-grained quartzite interbedded with fine- to medium-grained biotite-muscovite schist. The quartzite is light gray to buff in medium to thick beds where it forms almost all the section, and medium gray with greenish and purplish casts in thin beds where it is interbedded with pelitic schists. In both places it weathers slightly lighter. The Westboro Quartzite, a probable correlative to part of the Plainfield Formation is intruded by rocks dated as Precambrian (Nelson, 1975). The lower contact is an intrusive one, and the upper contact is faulted.

### Marlboro Formation (pre-Silurian)

Bedded to massive amphibolite forms the upper part of the Marlboro Formation (Emerson, 1917); Bell and Alvord, in press) in the report area. This amphibolite is generally medium to coarse grained and dark gray to nearly black; it weathers slightly lighter and contains a few beds of quartzose-feldspathic gneiss. The basal contact is faulted, and the upper contact with the Nashoba Formation is gradational, although it may be locally faulted. The Marlboro is correlative in Connecticut with the Quinebaug Formation of Dixon (1964). The Marlboro and the overlying Nashoba Formation and Tadmuck Brook Schist are considered pre-Middle Ordovician in age by Alvord, (1975) on the basis of radioactive-age dating.

Figure 1. Structural-stratigraphic blocks of the Worcester-Webster region, Massachusetts

Explanation: Heavy lines, faults, dashed where approximately located; fine lines, contacts; R.I., Rhode Island massif containing the Plainfield Formation; M-N, block containing Marlboro and Nashoba Formations and the Tadmuck Brook Schist; E, fault slivers of Eliot Formation and quartzite and metasiltstone-phyllite units; O, block and area of Oakdale Formation; P, block containing "Paxton Group"; B, block containing Brimfield Group. Intrusive rocks are not shown. Numbers denote locations of stops in the road log. Compiled from Barosh, 1974, and unpublished data by P.J. Barosh and G.E. Moore



| | | | |
|---|---|---|---|
| lower Paleozoic | Brimfield Group | Bigelow Brook Formation | fault |
| | "Paxton Group" | Southbridge Formation, lower part | |
| Silurian(?) or Devonian(?) | | Oakdale Formation | fault |
| Silurian | | Eliot Formation | |
| Silurian(?) | | Metasiltstone and phyllite<br>Quartzite | fault |
| pre-Silurian(?) | | Tadmuck Brook Schist | unconformity or fault |
| | | Nashoba Formation | |
| | | Marlboro Formation | fault |
| Precambrian(?) | | Plainfield Formation | |

Figure 2. Stratigraphic column for the Worcester-Webster region, Massachusetts

## Nashoba Formation (pre-Silurian)

The Nashoba Formation of Hanson (1956) was redescribed by Bell and Alvord (in press), whose work is summarized in this volume by Alvord. The Nashoba is used here in its original broader sense, which includes the Shawsheen and Fish Brook Gneisses at the base. Briefly, this very thick unit is characterizied by light- to medium-gray, medium- to coarse-grained, medium-bedded quartzose-feldspathic gneiss; beds of amphibolite and various types of schist and marble are common at certain horizons. The Nashoba is overlain by the Tadmuck Brook Schist at a slight angular discordance which probably represents an unconformity but could be due to faulting. The Nashoba correlates with the Tatnic Hill Formation of Connecticut.

## Tadmuck Brook Schist (pre-Silurian)

The Tadmuck Brook Schist of Bell and Alvord (in press) is only known, in this area from one exposure in the Worcester South quadrangle. It is composed of rusty weathering, silvery, medium- to dark-gray sillimanite biotite-quartz muscovite schist to quartz-chlorite-biotite-sericite phyllite. It is generally highly sheared, and its upper contact is faulted.

## Quartzite (Silurian?)

A thin quartzite exposed at one locality in the Worcester South quadrangle apparently correlates with the quartzite Peck (1975) referred to as Unit 1 in the Clinton area (Pec, in press). It is a light- to medium-gray, fine- to medium-grained, thin- to thick-bedded quartzite that weathers lighter gray. Its lower contact is faulted, and its upper contact appears conformable with the metasiltstone and phyllite unit.

## Metasiltstone and phyllite (Silurian?)

A thin unit of greenish to purplish medium-gray thin-bedded metasiltstone in the Worcester South quadrangle is apparently correlative with that in the Clinton quadrangle (Peck, 1975) referred to as Unit 2 by Peck (in press). The upper contact is covered, but Peck has reported that Unit 2 underlies Unit 3, the overlying Eliot Formation.

## Eliot Formation (Silurian)

The Eliot Formation is equivalent to the slate and phyllite, Unit 3, of Peck (1975, and in press), and probably also to Unit 4. It is a relatively uniform dark-gray sericite to muscovite phyllite to schist that is generally a well-bedded, thin-bedded unit with graded bedding it weathers to a lighter gray. It is commonly folded and is the only formation in the area to have a secondary foliation, not parallel to bedding, at several localities. The Eliot is correlated with the Silurian Eliot Formation of southern Maine (Hussey, 1962) on the basis of its distinct lithology and equivalent position in the stratigraphic sequence. Its upper contact is formed by a major fault in this area, but similar beds in the lowermost known Oakdale Formation to the west suggests that the Oakdale overlies it.

Peck (1975) considers the Eliot, along with the underlying Units 1 and 2, as Silurian or Devonian in age from a general correlation with formations to the north; Hussey (1962) correlated the Eliot and the two underlying units of southern Maine with Silurian rocks farther north in Maine.

### Oakdale Formation (Silurian? or Devonian?)

The Oakdale Formation, originally the Oakdale Quartzite of Emerson (1917), consists of medium- to dark-gray or greenish-gray thin-bedded metasiltstone to phyllite which weathers light to medium gray or greenish or brownish gray. It is well laminated locally and has some graded beds near the exposed base. At least one unit within the formation contains partings and thin beds of muscovite schist. The contact with the overlying basal beds of the Paxton Group appears faulted in the Webster area, but in the southwest part of the Worcester North quadrangle and adjacent part of the Worcester South quadrangle it appears conformable (fig. 1). The Oakdale Formation is considered Silurian(?) or Devonian(?) in age as it probably stratigraphically overlies the Silurian Eliot Formation, as does the equivalent basal Berwick Formation in Maine.

### "Paxton Group" (lower Paleozoic)

The Paxton Quartz Schist of Emerson (1917) has been divided into two formations by Moore (pers. comm.) which consist of medium-gray, thin- to medium-bedded, fine- to coarse-grained metagraywacke which weathers the same color or slightly darker with a brownish cast. The beds have a schistose to granulose structure and are composed mainly of quartz, biotite, and feldspar, which gives them a salt and pepper appearance. Calc-silicate-bearing beds occur at many horizons throughout the section. The upper part of the "Paxton" has been designated the Southbridge Formation informally by Moore (pers. comm.)(Pease, 1972), and the lower part is being redescribed as a new formation, which is equivalent to the Hebron Formation as mapped in the Eastford quadrangle (Pease, 1972). The lower part of the "Paxton" is fine grained and has generally thinner and more uniform beds than the Southbridge, which is medium to coarse grained and has fewer fine-grained beds. The contact between the two is gradational. The top of the Southbridge is bounded by the Black Pond fault.

### Bigelow Brook Formation (lower Paleozoic)

The Bigelow Brook Formation forms the basal formation of the Brimfield Group (Peper, Pease and Seiders, 1975). Its lower gneiss member forms the westernmost and uppermost part of the stratigraphy discussed here. The lower gneiss member consists of light- to medium-gray, weathering lighter to rusty, medium- to coarse-grained quartz-biotite-feldspar gneiss interbedded with schist. Some gneiss is calc-silciate bearing, and sillimanite is common in the member. The Bigelow Brook Formation is considered to overlie the Southbridge Formation stratigraphically (Peper, Pease and Seiders, 1975).

Units at the top of the Brimfield Group are considered Devonian(?) by correlation with units to the north in New Hampshire; the Brimfield and "Paxton" Groups were designated Ordovician(?) to Lower Devonian by Peper, Pease and Seiders (1975). The correlation of Eliot with Silurian rocks probably restricts the age to Silurian(?) or Devonian(?).

## DESCRIPTION

(7½-minute quadrangle maps covered on this trip are the Leicester, Oxford (Stops 4 and 5), Southbridge (Stop 8), Webster (Stops 6 and 7) and Worcester South (Stops 1,2 and 3))

## ROAD LOG

| MILEAGE | |
|---|---|
| 0 | Toll booth at Auburn Exit, interchange 10, of Massachusetts Turnpike. Oakdale Formation in roadcuts. (For description along Massachusetts Turnpike from Boston to interchange 10 see road log for "Faults and related deformation in the Clinton-Newbury-Bloody Bluff fault complex of eastern Massachusetts"). |
| 0.1 | Veer left, entrance Rt. 12 north-290, Auburn-Worcester, and stay left following 290 East signs. |
| 3.9 | Worcester town line. |
| 4.5 | Right on exit 11, College Square, Worcester. |
| 4.8 | Right on College St. (becomes Pakachoag St. to south) Holy Cross College on the left. |
| 5.2 | Right on Kendig St. (a dirt street), go 100 m, and park on right. Walk west down road 40 m, turn left off road, and go about 60 m south to extensive outcrops around top of knoll--College Hill. STOP 1, Eliot Formation, medium to dark gray thin bedded. 0.5-to2-cm beds, meta-mudstone-phyllite with graded bedding. The formation appears to have formed as a distal turbidite sequence (Peck, in press). Sedimentary features very well shown. Overturned beds present. |
| 5.3 | Return to College St. and turn right. |
| 5.5 | Veer left. |
| 7.3 | Outcrops of Eliot on left 50 m north of powerline. |
| 7.6 | Low outcrops of Eliot on right and scattered outcrops next 0.2 mile on both sides of road. |
| 7.9 | Right just before overpass (Massachusetts Turnpike). Do not go under overpass. |
| 8.1 | Left onto Swanson Road. Pond on right is all that is left of Auburn Pond that extended to Massachusetts Turnpike. Shopping mall area created by leveling a drumlin at the present site of Sears and filling in the pond. |

8.4 Left at signals onto Southbridge St.

8.6 Right 100 m beyond Gino's. Pull off pavement on right, near corner and park. Walk to low outcrops in gravel pit to north. STOP 2, Oakdale Formation, medium- to dark-gray metasiltstone and metamudstone, well bedded in 1- to 35-cm-thick beds. Graded bedding in the thinner more pelitic beds, laminations in the more quartzose slightly coarser grained beds. Sedimentary features are well shown for the Oakdale, which generally appears as a more uniform thin-bedded metasiltstone, but which has a deceptively massive-looking appearance in roadcuts, such as at the Auburn exit, and lacks obvious graded bedding. Refracted cleavage across the finer grained part of graded beds resembles cross-bedding. Many small folds and some pseudofolds (ptygmatic quartz veins). The thinner, finer grained graded-bedded layers, which are unusual in the Oakdale, may indicate that this lower part of the formation was formed in an environment transitional from that of the Eliot. Continue down side road.

8.8 Rejoin Southbridge St., turn right.

9.1 Pass under Massachusetts Turnpike.

9.4 Right on Water St. (just north of Auburn Elks), go 50 m, and park on right. Rock roadcuts on both sides. STOP 3, (extra stop if time permits). Oakdale Formation, medium- to dark-gray thin-bedded metasiltstone, few graded beds. Stop demonstrates the apparent differences between smoothed weathered outcrop and fresh blated roadcut exposures. The formation is as well bedded as at Stop 2, although it does not appear to be. Foliation parallels bedding. Outcrop is highly contorted and folded and has overturned beds in places. Many nonsystematic folds.

9.5 Left onto Oxford St., just beyond underpass beneath Rt. 290.

9.9 Right on Southbridge St., Rt. 12 South.

11.2 Right bend at signals at junction of Rts. 12 and 20, continue west. Driving over Oakdale Formation.

11.9 Left onto Rt. 12 south Oxford-Webster. Biotite quartz monzonite forms the hill to the left; the rigde to the right is composed of muscovite quartz monzonite, "Fitchburg granite."

12.4 Outcrop on right is silicic laminated Oakdale. A short distance ahead the intrusive rocks on either side merge, pinching out the Oakdale. The Oakdale reappears at the same position about a mile farther southwest.

13.5 Outcrops of quartz monzonite on both sides of valley. Intrusive rocks in this area tend to be relatively long and narrow. Some have intruded fault zones, as shown by disjunctions between rocks on either side of the intrusive rock and by xenoliths of mylonite. Some also have moved along contacts.

14.1 Clinton-Newbury fault zone traverses valley on left and crosses road.

14.5 Boulders on left of a variety of intrusive rocks from the fault zone; many are highly sheared to mylonitized. Outcrop of Nashoba Formation on left just beyond diner. Large Pleistocene river came down the valley and disgorged sediments into a lake here, building a large flat-topped delta to the south on which Oxford center is built.

16.5 Oxford Center left onto Sutton Ave. east; sign points to Rt. 52, Webster.

17.1 Cross over Rt. 52 and park on right just beyond entrance ramp to Rt. 52 North, Auburn-Worcester (present end of interstate and entrance unmarked). Carefully walk across road to outcrops along entrance ramp to Rt. 52 North from west lane Sutton St. STOP 4, Contact Marlboro Formation (Quinebaug Formation) with Nashoba Formation of Hanson (1956) (Tatnic Hill Formation). Well-bedded volcaniclastic sequence which has foliation paralleling bedding. Amphibolite at south end of cut, and also underlying the valley to south, forms the top of the Marlboro Formation, designated Quinebaug in Connecticut by Dixon (1964). The Marlboro is dark-gray layered amphibolite containing a few beds of quartzose-feldspathic gneiss. Much of the upper part of the formation has 0.5- to 10-cm thick beds, but beds 1 m or so thick are not uncommon. This bedded amphibolite correlates with the Sandy Pond **Amphibolite Member** of the Marlboro of Bell and Alvord (in press). To the north is the light- to medium-gray, medium-bedded quartzose-feldspathic gneiss that forms the most common lithology in the Nashoba Formation, designated Tatnic Hill Formation in Connecticut (Dixon, 1964). This gneiss is probably equivalent to the Shawsheen Gneiss of Bell and Alvord (in press) and Alvord, (this volume). Note the high metamorphic grade here in contrast to that at the previous stops. The few large garnets found in the gneiss here are unusual. Minor faulting occurs at the contact, and either the contact is repeated or a bed of amphibolite occurs near the base of the gneiss. The rocks here are highly sheared and faulted as they are just above a major regional thrust that underlies the valley to the south. Light-gray pegmatite, both foliated and nonfoliated, is present along many of the shears and thrust faults.

Back up carefully and enter entrance ramp Rt. 52 North. Pass under Sutton Avenue and turn right onto Exit 4 West Sutton Avenue, Oxford, and pass outcrops of STOP 4. Enter Sutton Avenue west, cross over Rt. 52, and turn right into entrance to Rt. 52 South, Webster - Thompson Ct.

18.4 Pass under Sutton Avenue a second time. You should now be heading south on Rt. 52. Valley underlain by amphibolite of Marlboro Formation.

18.8 Crossing major north-dipping thrust fault which separates the structural block containing the Marlboro and Nashoba rocks on the northwest from those of Rhode Island massif to the south. South of the fault is a broad northwest-plunging anticline rimmed by quartzite of the Plainfield Formation intruded by syntectonic intrusive gneiss, approximately quartz monzonite in composition.

19.4 Crossing anticlinal axis.

19.5 Intrusive gneiss crops out on both sides of roadway, the intruded quartzite beds capping the outcrop on the left. More quartzite is present along northbound lanes. The intrusive rock is moderately to strongly foliated, the feldspars being generally rounded rather than sheared and fractured. The rock has generally undergone alteration, which has produced pink feldspar and has chloritized the mafic minerals. Faults cut the rock here; several nearly parallel the road, dipping steeply to the west, and a few are approximately perpendicular to the road.

19.8 Pass under Holbrook Street.

21.3 - 22.1 Outcrops of Plainfield Formation along the road.

22.2 Right on exit 2, Rt. 16, Webster-Douglas, drive through cut in Plainfield Formation.

22.5 Right on Rt. 16 west, go about 50 m and turn left into parking lot (at north shore of Lake Webster) and park. Walk back to the roadcut just driven through. STOP 5, Plainfield Formation; greenish to purplish medium-gray thin-bedded interbedded dirty quartzite and schistose pelitic beds. Beds range from 0.5 to 30 cm in thickness but are mostly 2 to 5 cm thick. Foliation parallels bedding. The beds are crinkled to contorted, which is typical in this region of units of alternating beds of different competence. Overlying beds to west become more quartzitic and massive, forming light-gray to buff thin- to medium-bedded quartzite. Beds at west edge of outcrop, next to the fire plug, are broken up; a major fault lies a short distance to the west, separating the Plainfield from the Marlboro-Nashoba rocks. Left from parking lot, continue west.

22.7 Intersection Rt. 16 and Rt. 12. (Lunch stop, left, south, on Rt. 16, 0.4 miles farther, turn left on New Beach Dr. and pass under Rt. 52 for Webster Memorial Beach at end of peninsula for lunch stop. Peninsula is part of a head of glacial outwash. Several ice stands are recorded in the lake by paired peninsulas. Return to Rt. 16 and Rt. 12 intersection and turn left, west, onto East Main Street, Route 12. Add 1.6 miles to mileage for this loop.) Driving over Nashoba Formation.

23.6 Veer left at signal. The boulders on the left are composed of Eliot Formation and porphyritic quartz monzonite. Driving over southern end of fault sliver of Eliot, which underlies Webster center.

23.9 Right at signals, Webster center.

24.3 Dudley town line. Driving over intrusive complex of quartz monzonite.

24.7 Continue straight, west, on West Main Street, Rt. 197, next outcrop on left muscovite quartz monzonite.

25.7 Veer left at road split.

27.4 Crossing Center Road. Entered onto Oakdale formation near top of hill to east. Weathered Oakdale in bank on southeast corner. Muscovitic part of Oakdale here. Muscovitic schist partings to 2-cm-thick beds between greenish medium-gray laminated silicic metasiltstone in 2- to 8-cm-thick beds. This unit is rarely exposed but appears to be widespread.

27.8 Thompson town line, Connecticut border.

28.1 Quinebaug, right on Rt. 131 North. Driving up Quinebaug River valley, which follows a northwest-trending fault zone (fig. 1).

28.4 Dudley town line, Massachusetts border.

28.7 Quinebaug River crossing. Entering onto the lower part of the "Paxton Group," a thin- to medium-bedded meta-graywacke.

30.4 Outcrop in creek 20 m west of road junction is part of a gradational sequence between the lower part of the "Paxton" and the Southbridge Formation.

30.6 Right at West Dudley, drive between factory buildings, cross bridge and up gravel terraces.

31.0 Right at north end of bridge over flooded railroad cut.

31.1 Veer right onto dirt road, watch out for gravel trucks, travel 0.2 mile and turn around in entrance to overgrown road on left, return 0.1 mile and pull off to right side of road at the spring (year-around flow of cold water). STOP 6, Gradational sequence between the lower part of the "Paxton Group" to the east and the overlying Southbridge Formation to the west. Medium-gray thin- to medium-bedded metagraywacke. The rocks are slightly to moderately foliated parallel to bedding and vary between a schistose and granulose structure. The bedding in cuts appears thicker than it is, as weathering of many of the thicker appearing beds commonly reveals that they are composed of two or more beds. The fine-grained beds at the east end of the outcrop are typical of the lower part. Towards the west end, medium-to coarse-grained beds more typical of the Southbridge appear. The pegmatite seen here commonly occurs in both formations.

31.5 Return to split in road and make a sharp right turn, continue 0.1 mile to curve in paved road and pull off to left onto dirt road under powerlines, and park. Walk north about 60 m to good exposure of bluff northwest of road. STOP 7, Southbridge Formation. Typical Southbridge outcrop, coarser grained, slightly thicker, and more irregular beds than at the last stop.

32.3 Return to Rt. 131 and turn right, extensive exposures of Southbridge along an old railroad cut that follows northeast side of river.

32.7 Southbridge town line.

34.4 Passing bridge on right. Good exposures of Southbridge at bluff at other side of the bridge. The beds here are slightly finer grained and thinner bedded than ususal in the Southbridge and are more like those at STOP 6.

35.5 Outcrops of Southbridge.

35.6 Stay right passing traffic circle, and cross the Quinebaug River.

36.2 Veer right onto Worcester Street. Road traverses west side of a valley controlled by the Black Pond fault, which separates the Southbridge on the east from the Bigelow Brook Formation on the west. Scattered outcrops of Beigelow Brook along ridge to left.

36.9 Park on right and walk across the street to the outcrops on the north side of the Central Retreading, Inc., building. STOP 8, Bigelow Brook Formation, lower gneiss member. Medium-gray thin- to medium-bedded quartzose feldspathic gneiss interbedded with thin-bedded darker schist. Some gneiss units contain calc-silicate minerals and may have a slight greenish cast. Relict graded bedding is present locally. The Bigelow Brook units are distinctly coarser grained and have more schistose beds than those of the Southbridge Formation. The foliation parallels the bedding. The metamorphic grade increases westward from Dudley; this outcrop is very close to the sillimanite-orthoclase isograd. Some shearing, related to the fault to the east, is present. Continue northward, except those going towards southeastern Connecticut or Rhode Island, who should return to Southbridge and go east on Rt. 131.

37.7 Charlton town line.

41.0 Rt. 20, end of guide. Left for those going west or south; 6 miles to Sturbridge for Rt. 15 south or Massachusetts Turnpike west. Right for those going towards Boston or northeast; 10 miles to Auburn for Rt. 290 or Massachusetts Turnpike east.

## References


Alvord, D.C., 1975, Preliminary bedrock geologic maps of the Westford and Billerica quadrangles, Middlesex County, Massachusetts: U.S. Geol. Survey open-file report 75-387.

_____1976, Field guide to the Pre-Silurian eugeosynclinal metamorphic work sequence occurring between the Bloody Bluff and Clinton-Newbury faults, Concord, Billerica, and Westford quadrangles, Massachusetts: this volume.

Barosh, P.J., 1974, Preliminary bedrock geologic map of the Webster quadrangle, Massachusetts and Connecticut: U.S. Geol. Survey open-file report 74-192.

Bell, K.G. and Alvord, D.C., in press, Pre-Silurian stratigraphy of northeastern Massachusetts: in Page, L.R., ed., New England Stratigraphy: Geol. Soc. America Mem. 148.

Dixon, H.R., 1964, The Putnam Group of eastern Connecticut: U.S. Geol. Survey Bull. 1194-C, 12 p.

Emerson, B.K., 1917, Geology of Massachusetts and Rhode Island: U.S. Geol. Survey Bull. 704, 132 p.

Hanson, W.R., 1956, Geology and mineral resources of the Hudson and Maynard quadrangles, Massachusetts: U.S. Geol. Survey Bull. 1038, 104 p.

Hussey, A.M., 2d, 1962, The geology of southern York County, Maine: Maine Geol. Survey Spec. Studies Ser. no. 4, 67 p.

Lundgren, Lawrence, Jr., 1962, Deep River area, Connecticut: Stratigraphy and structure: Am. Jour. Sci. v. 260, p. 1-23.

Nelson, A.E., 1975, Bedrock geologic map of the Natick quadrangle, Middlesex and Norfolk Counties, Massachusetts: U.S. Geol. Survey Geol. Quad. Map GQ-1208.

Pease, M.H., Jr., 1972, Geologic map of the Eastford quadrangle, Windham and Tolland Counties, Connecticut: U.S. Geol. Survey Geol. Quad. Map GQ-1023.

Peck, J.H., 1975, Preliminary bedrock geologic map of the Clinton quadrangle, Worcester county, Massachusetts: U.S. Geol. Survey open-file Report 75-658.

_____in press, Silurian and Devonian stratigraphy in the Clinton quadrangle, central Massachusetts: in Page, L.R. ed., New England stratigraphy: Geol. Soc. America Mem. 148.

Peper, J.D., Pease, M.H., Jr. and Seiders, V.M., 1975, Stratigraphic and structural relationships of the Brimfeild Group in northeast-central Connecticut and adjacent Massachusetts: U.S. Geol. Survey Bull. 1389, 31 p.